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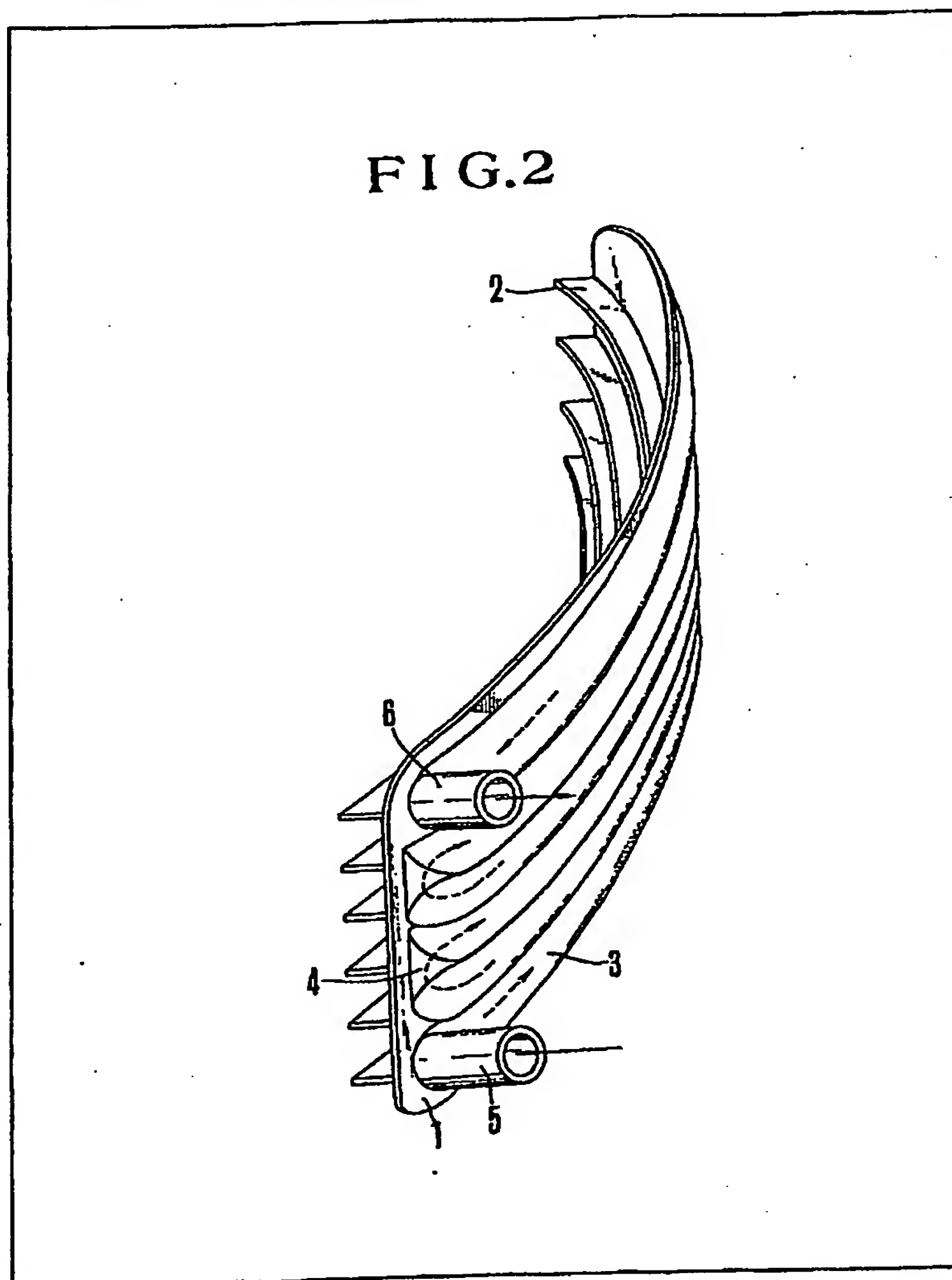
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(54) Water-cooled panel particularly  
 for use as a furnace chamber wall  
 member

(57) A water-cooled panel (e.g for use  
 as a furnace chamber wall member)  
 comprises a plate 1, a plurality of fins 2  
 upstanding from one face of the plate  
 (said fins in use facing the furnace  
 interior), and a plurality of channels 3  
 affixed (e.g by welding) to the other  
 face of the plate and defining therewith

a cooling water path with an inlet  
 connection at one end and an outlet  
 connection at the other end, and at least  
 one fixture (e.g 7, Figures 3 and 4) being  
 secured at said other face for mounting  
 the panel (e.g to the furnace shell). The  
 invention includes the dimensional re-  
 lationships of the plate, fins and chan-  
 nels.



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FIG. 1

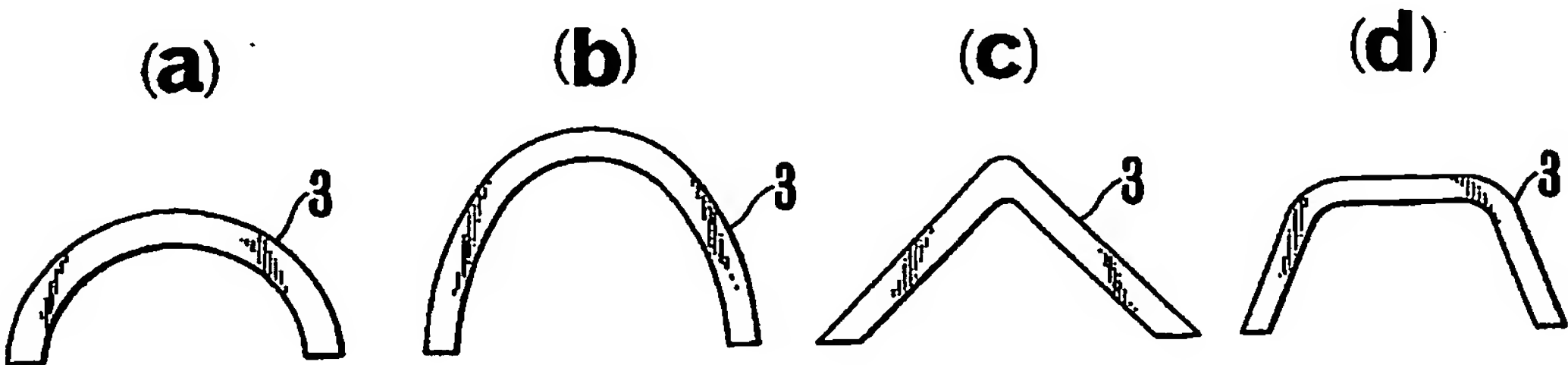
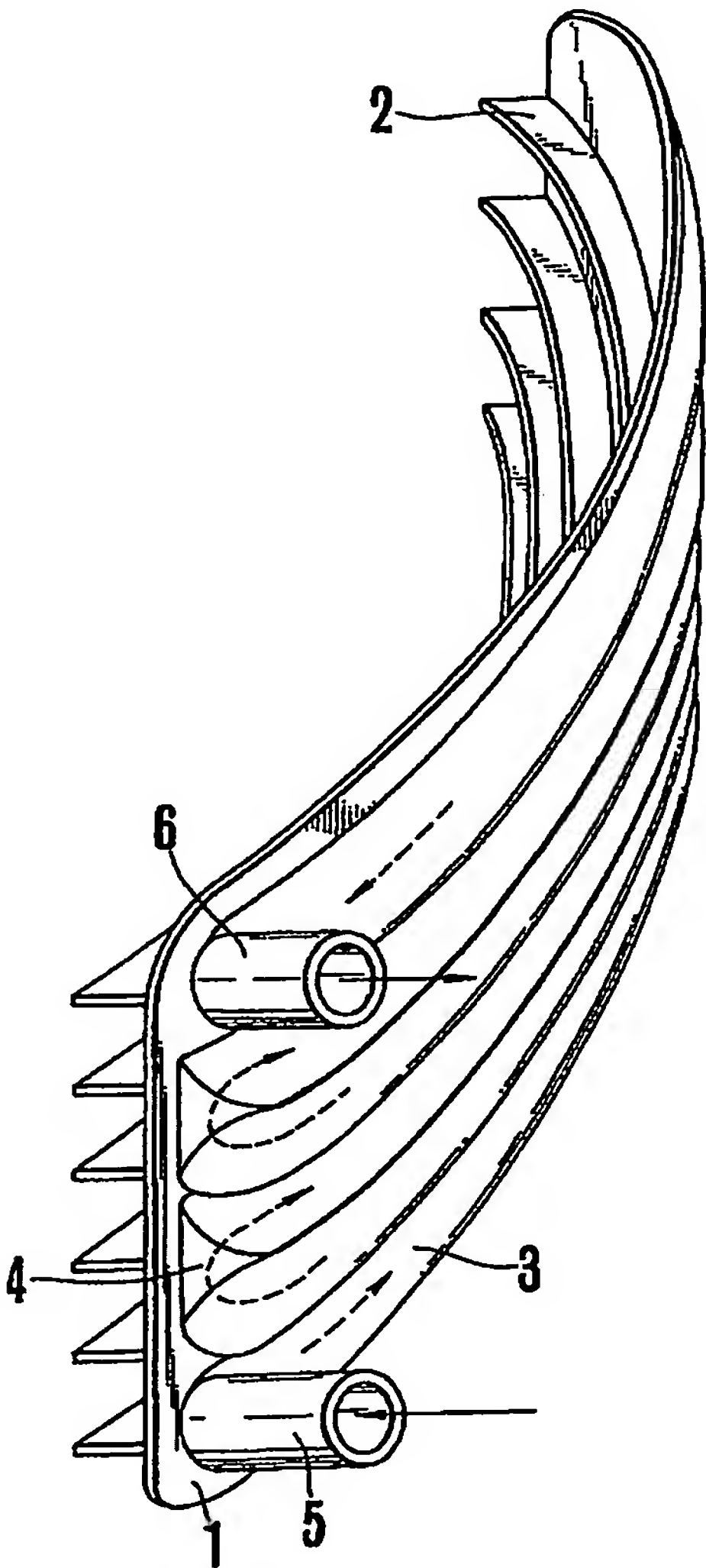


FIG. 2



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FIG.3

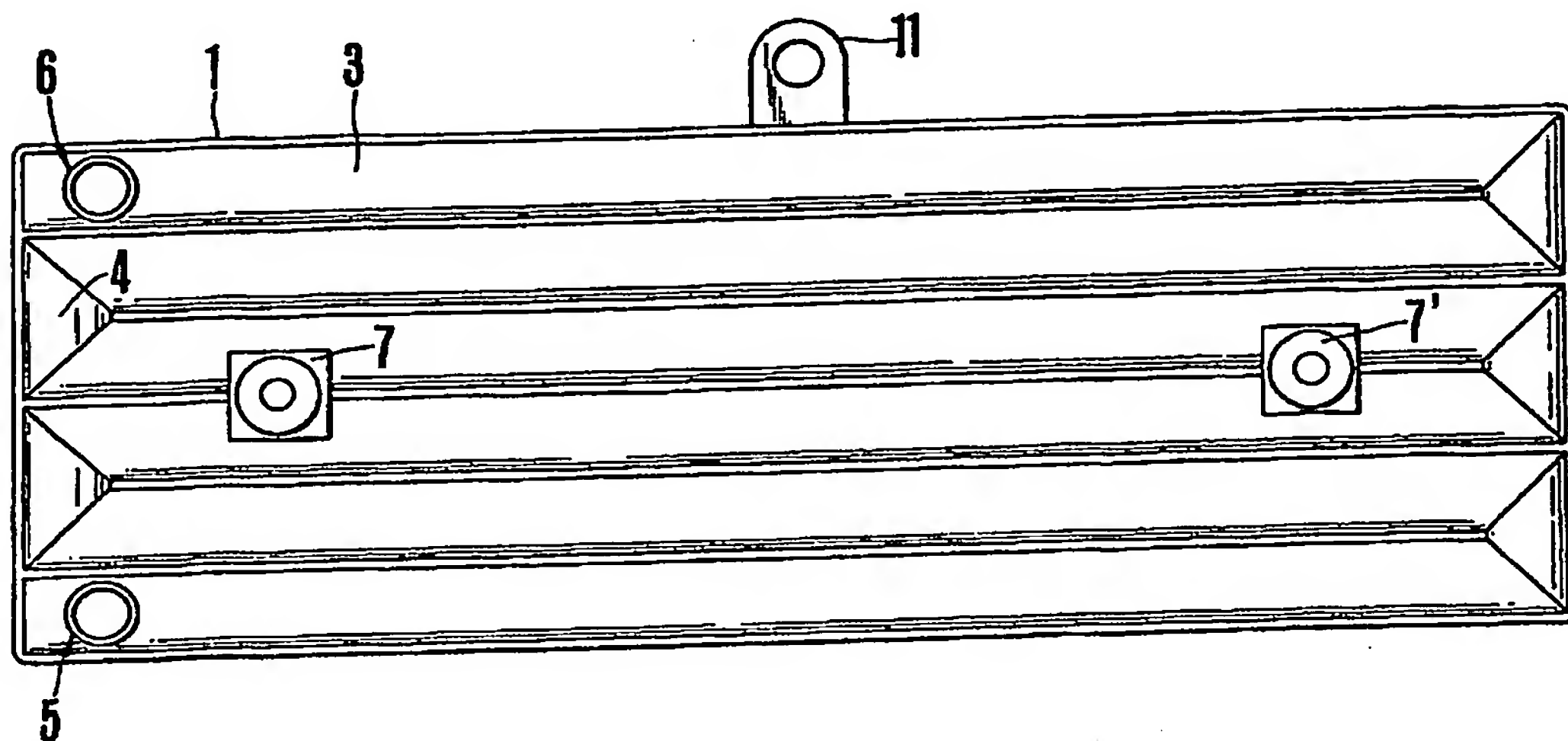
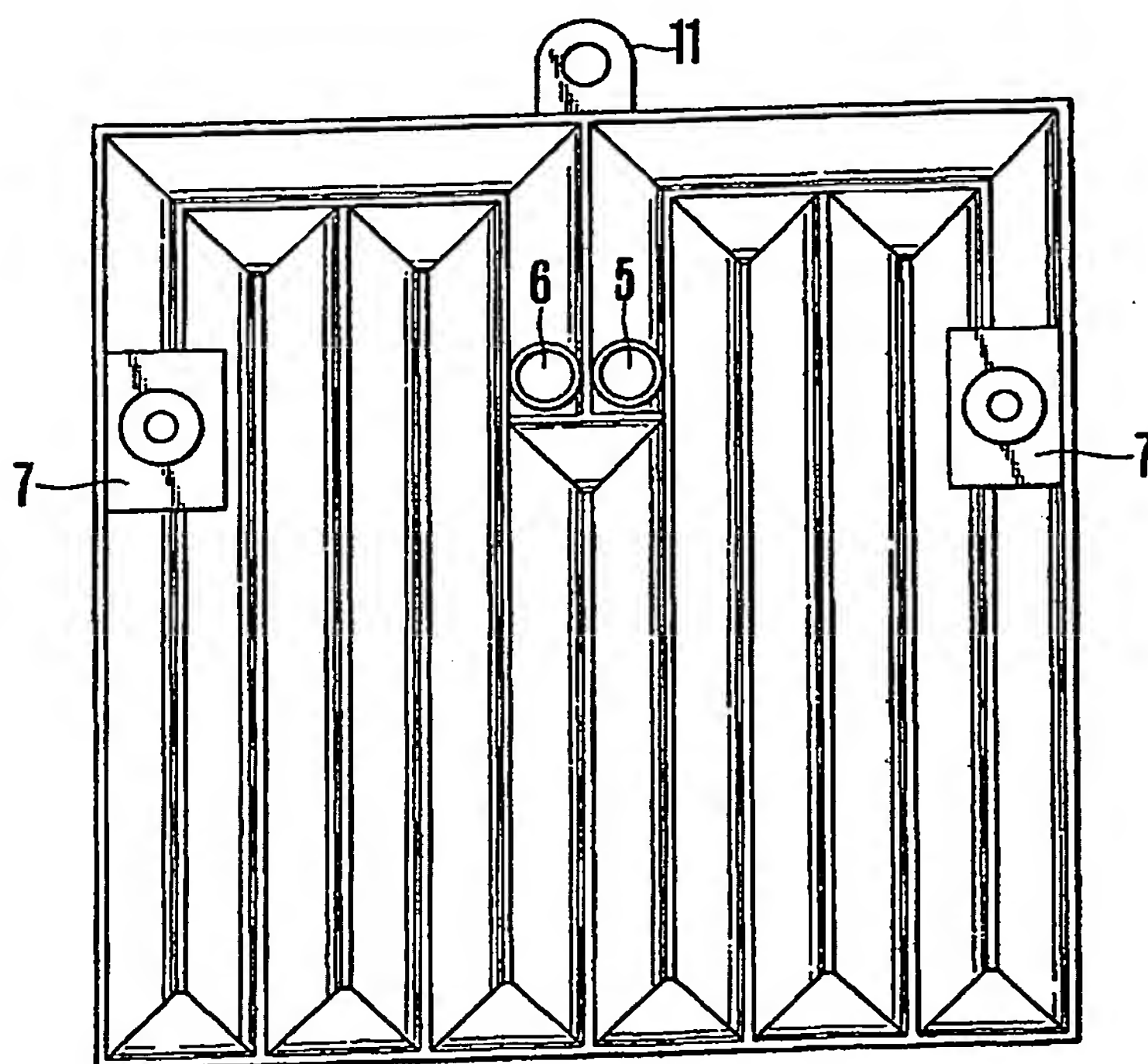


FIG.4



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FIG.5

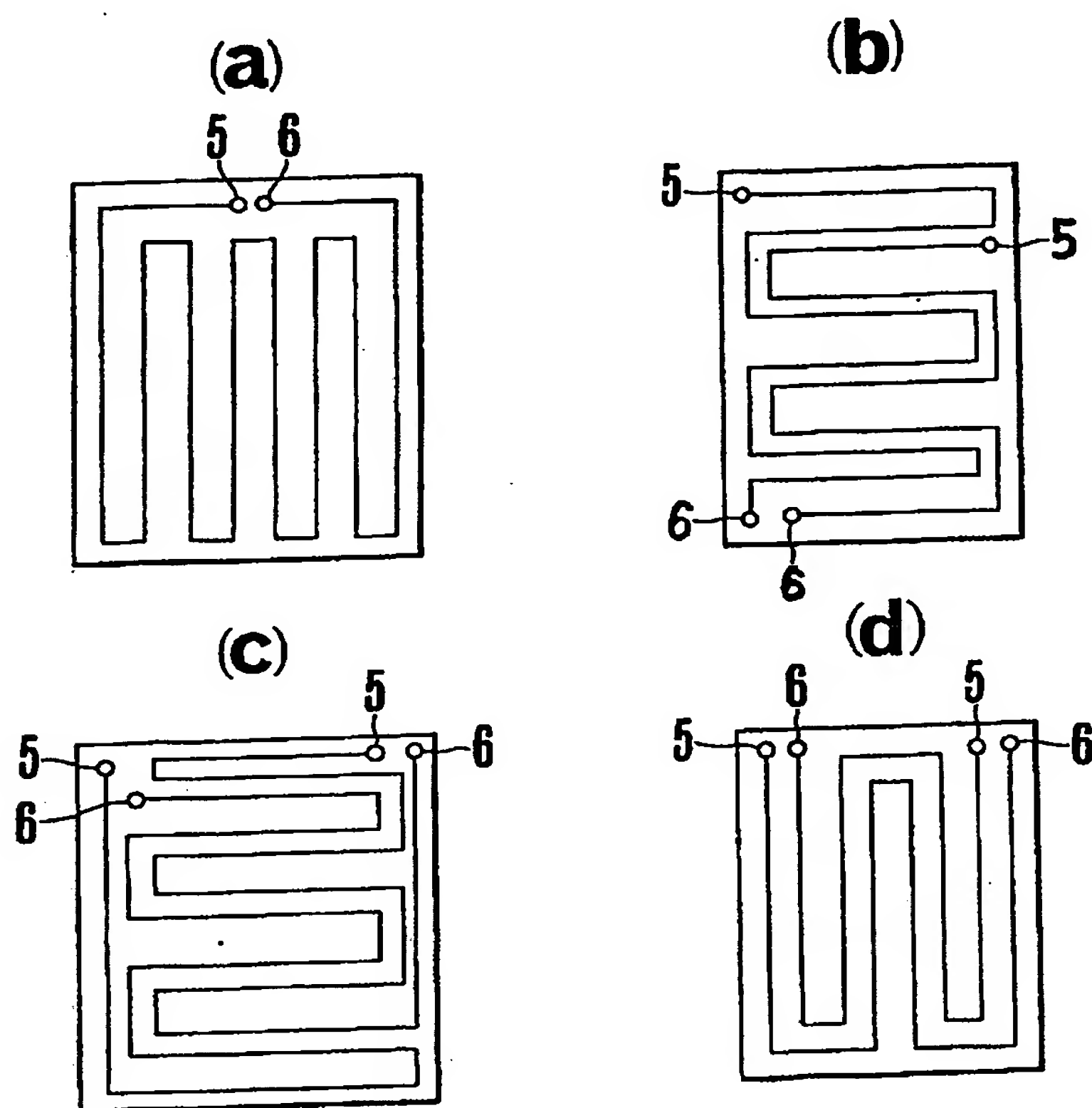


FIG.7

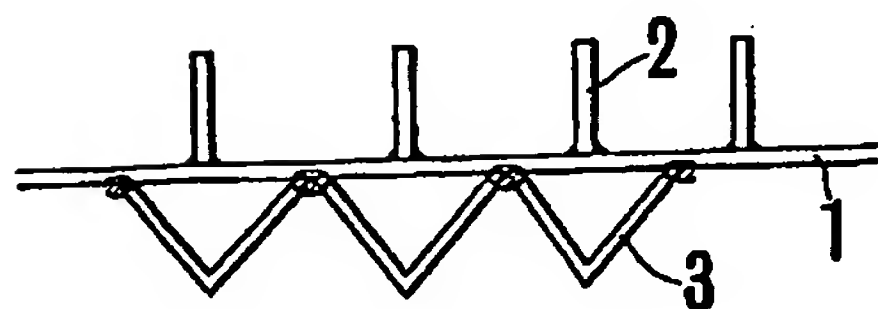
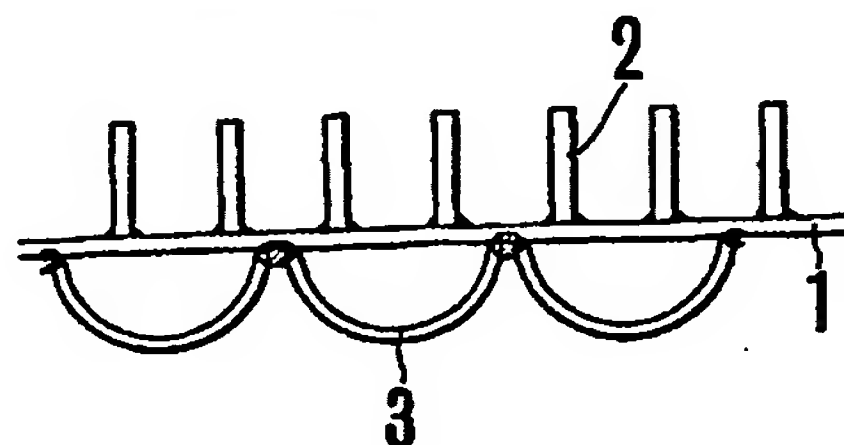


FIG.6



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FIG.8

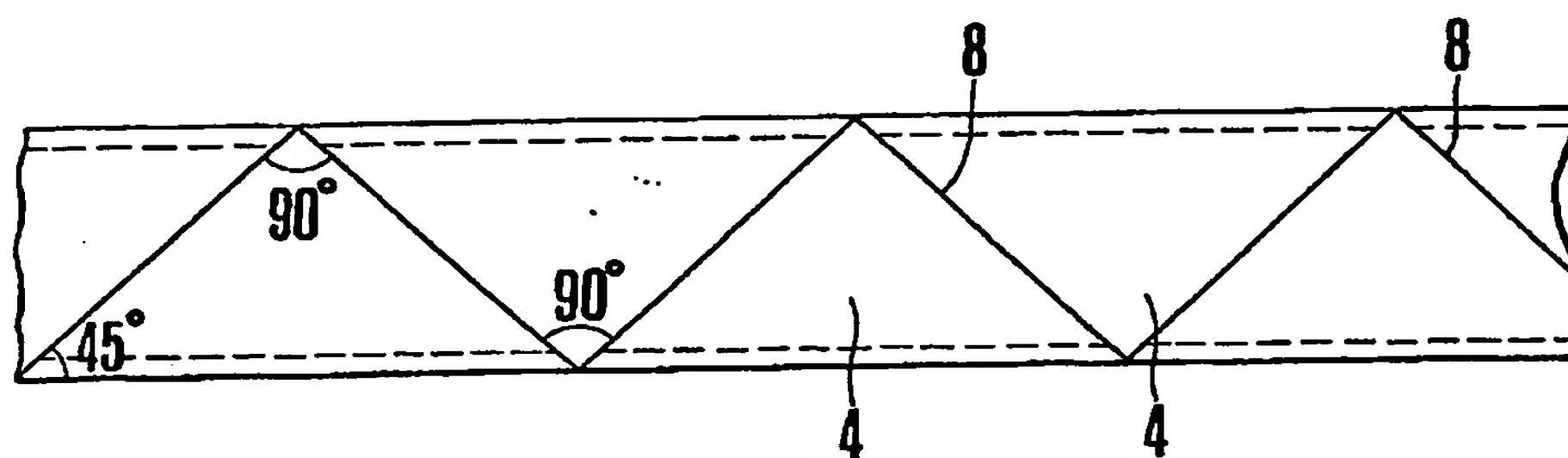
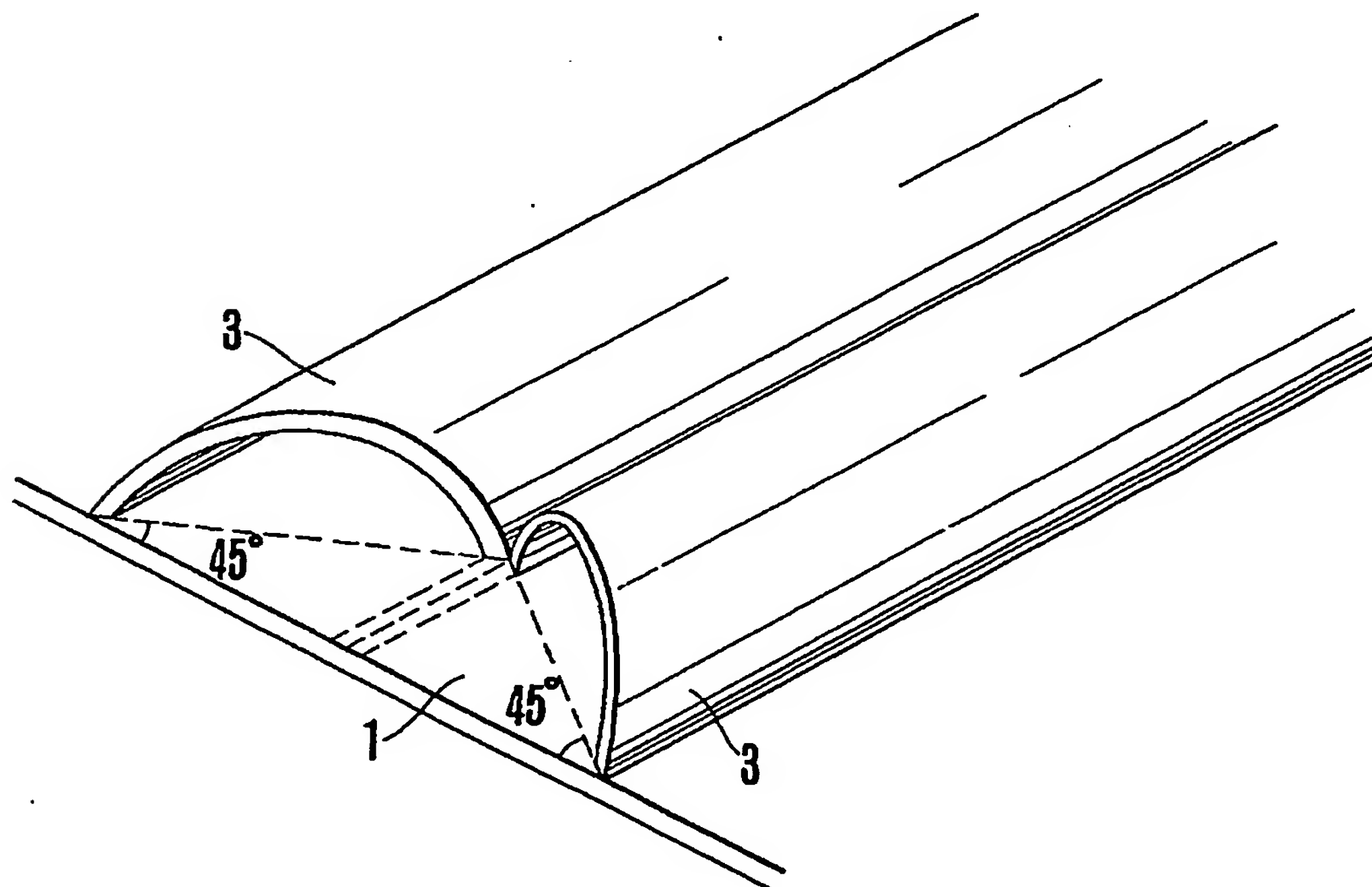


FIG.9



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FIG.10

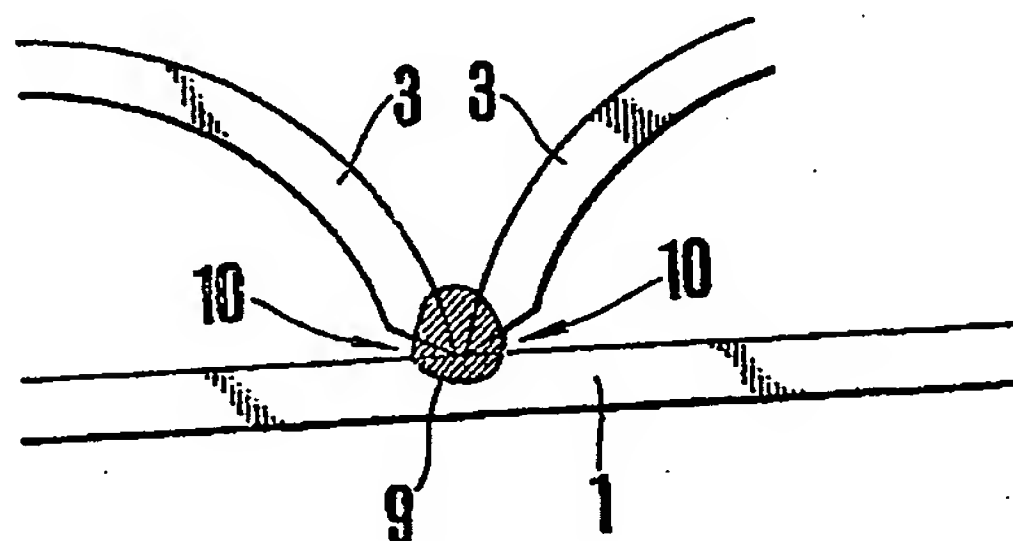
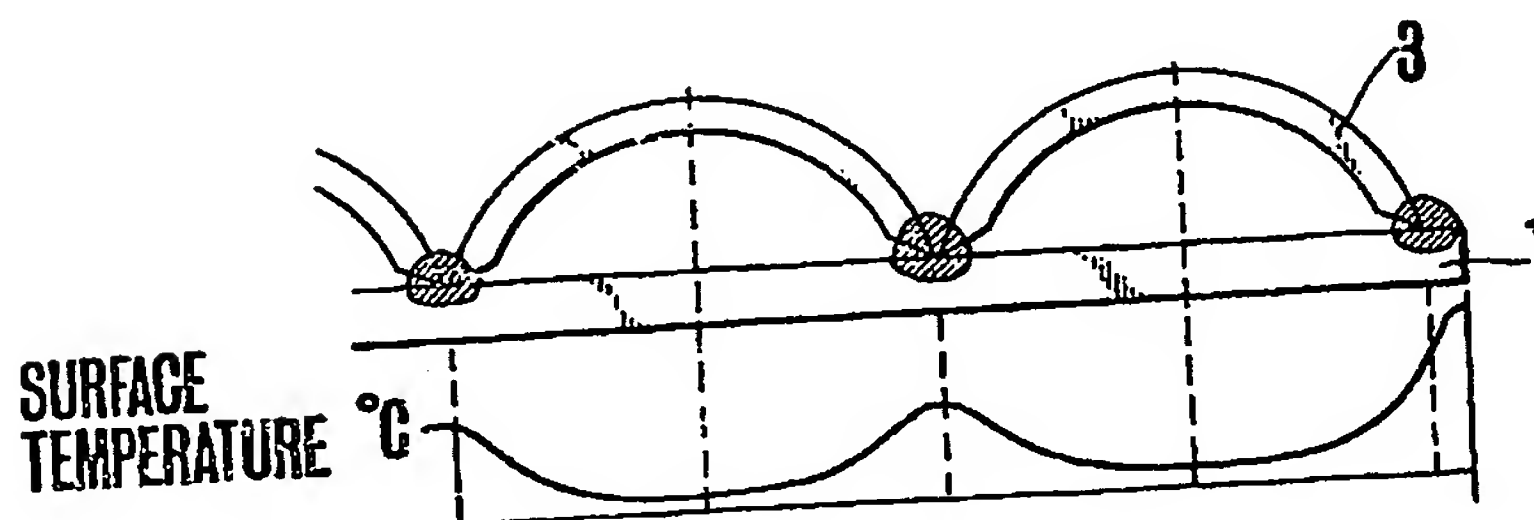


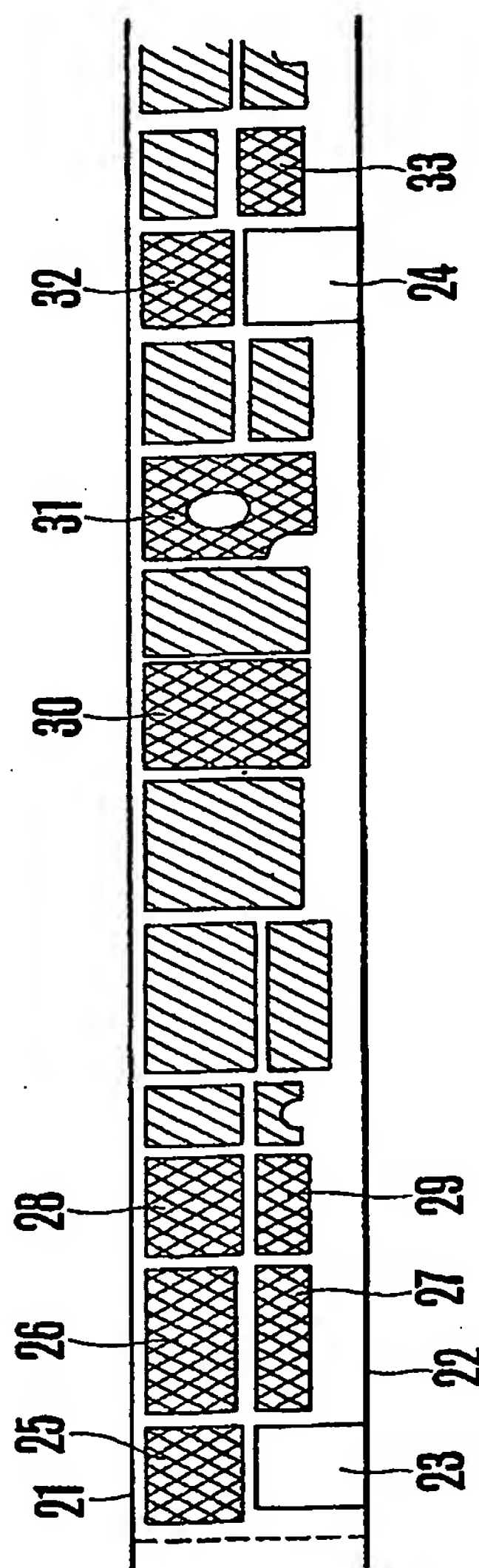
FIG.12



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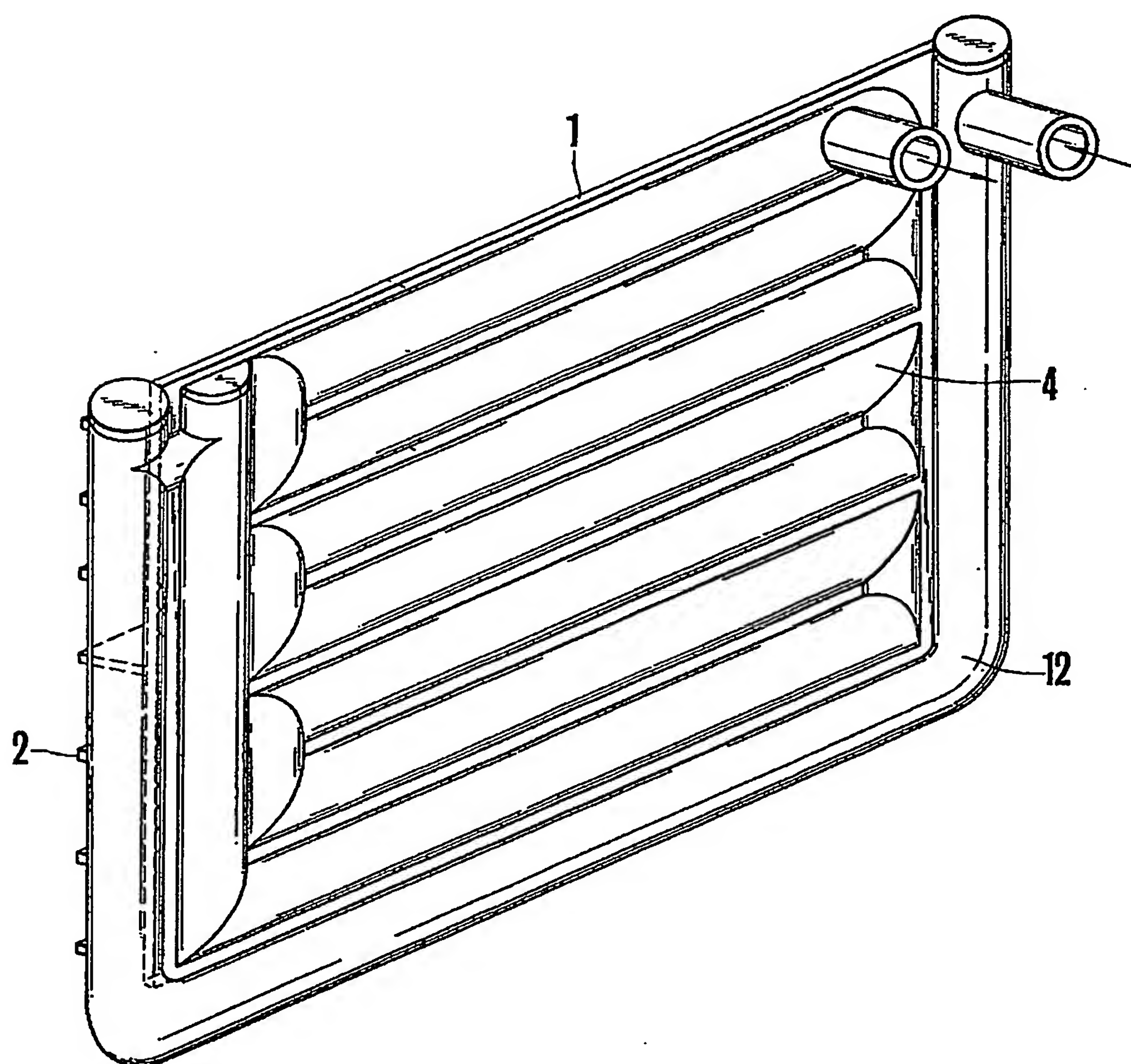
FIG.11



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FIG.13

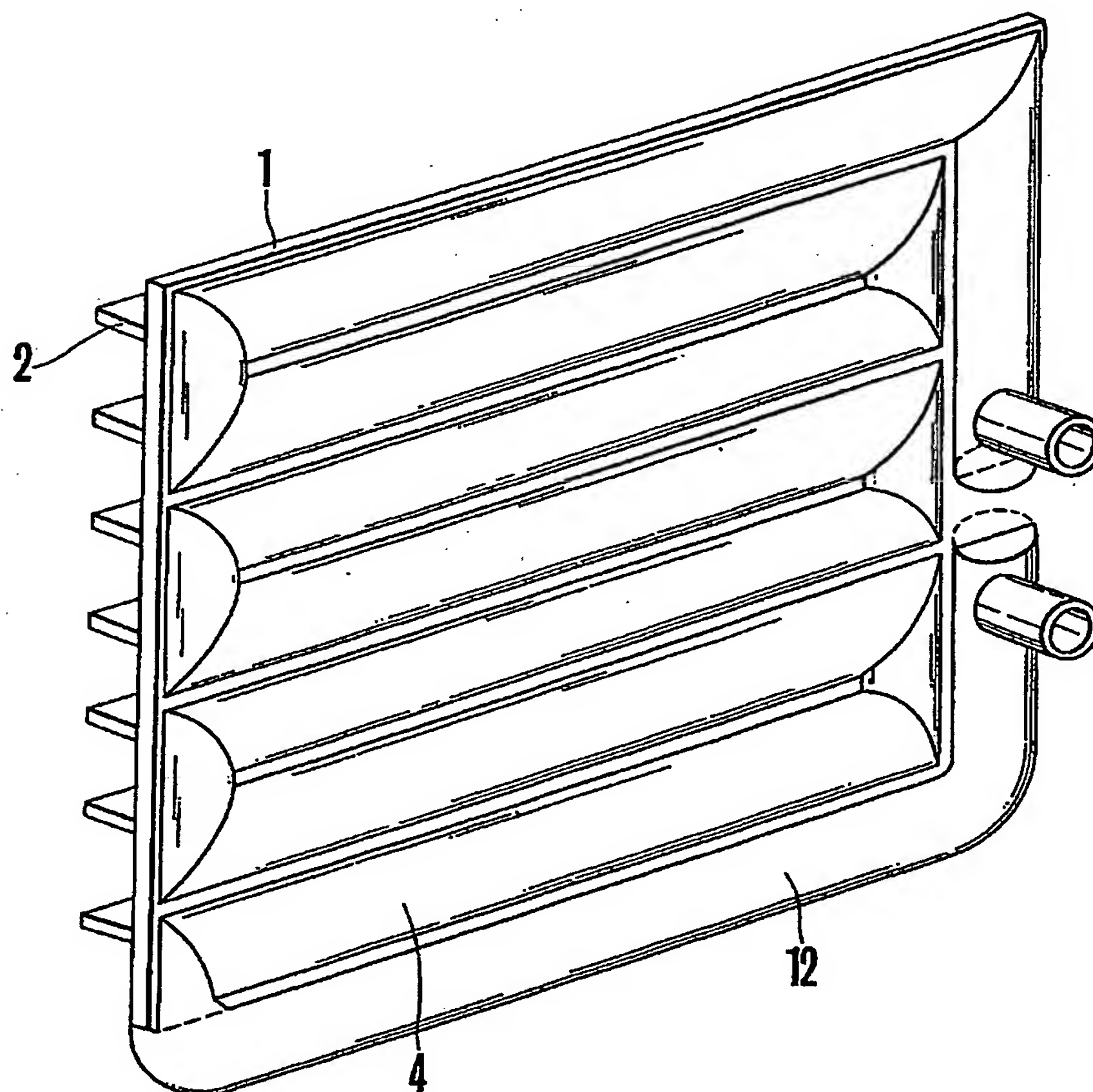




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FIG.14



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## SPECIFICATION

## Water-cooled panel for use in an electric furnace

5 This invention relates to a water-cooled panel suitable for use in an electric arc furnace employed in steel-making.

Recently, UHP (ultra-high power) operations are gaining wide acceptance in the steel manufacturing industry. These operations employ an electric furnace equipped with a transformer the capacity of which would be considered to be too great in the conventional sense relative to the melting capacity of the furnace, because the heat of the arc is so intense that the side walls tend to be extensively and severely damaged while the melting rapidly proceeds. A variety of measures have been taken to protect the side walls of such furnaces, and one of these measures is the use of metallic wall elements in place of walls made of refractory materials. Typical examples of metallic wall elements are a cast iron block with cooling water conduits passing there-through and a water-cooled panel fabricated by welding with baffle plates therewithin to form water passages, as disclosed for instances in U.S. Patent Specifications Nos. 3843106 and 3940552. However, these known examples suffer from various disadvantages. The former wall element has the shortcomings of heavy weight, small cooling capacity, high manufacturing cost, and so on, whereas the latter panel is susceptible to heat stress distortions due to its construction, particularly at the sides where cooling by water is also poorly effected, and this leads to the chance of water leakage.

35 It is an aim of this invention to provide an electric arc furnace panel which at least reduces or is free from the shortcomings of the known examples mentioned above, and thus is relatively safe in operation, easy to maintain and involves relatively low manufacturing and installation costs.

According to this invention, there is provided a water-cooled panel adapted for use in an electric furnace, which panel comprises a metal base plate of 6 to 30 mm thick, a length of not more than 1/8 of the furnace shell circumference and a height of not more than 2/3 of the height of the furnace side walls, a plurality of fins projecting from the face of the base adapted to confront the furnace interior, each fin having a thickness of 1/3 to 4/3 that of the base plate and spaced from the adjacent fin by from 40 to 100 mm, each fin projecting by at least 30 mm from the base plate, a cooling water path defined by a plurality of metal channels each defining a water flow area of from 4 to 56 cm<sup>2</sup> and having a thickness of from 1/3 to 4/3 that of the base plate, each channel being welded to the base plate on the face thereof opposed to that carrying the fins, a connecting element being welded to the base plate and to adjacent channel ends to complete a continuous water flow path from one channel to the adjacent channel, the channels at the ends of the flow path being provided with a water inlet and a water outlet, and at least one fixture mounted on the face of the panel opposed to the fins for fastening the panel to the shell of the furnace, the points of attachment of the fins to one face of the

base plate being non-aligned with the points of attachment of the channels to the other face of the base plate.

When in use, the panel of this invention is affixed within a furnace side wall with the fins facing the furnace interior. Water is circulated through the cooling water path to cool the panel when the furnace is operated, and then slag becomes deposited on the fins to form a thermally insulating coating. The panel can be located at points of high temperature loading in the furnace wall, especially in a UHP furnace.

The essential characteristics for the base plate of the water-cooled panel according to the present invention are that it conducts heat and yet is heat resistant to withstand the intense arc heat and be capable of holding slag coating deposited on the fins, whilst being water-cooled from the side thereof away from the furnace interior. The base plate must also exhibit sufficient rigidity to remain intact in the furnace shell. The base plate is, therefore, preferably made of a metal such as a rolled steel plate, a cast steel plate or a cast copper plate, both from the view-points of the heat loading and economics. A steel plate is used in the specific embodiments of the present invention described below.

The size of the base plate is basically determined by two factors; economics in manufacturing and ease of handling and installation. The panel should have a length of not more than 1/8 of the furnace shell circumference into which the panel is to be installed and a height of not more than 2/3 of the height of the furnace side walls. Though a relatively small base plate would be selected for installation at a special location in limited cases, a general purpose panel would have a horizontal length of not less than 1/24 of the circumference of the furnace shell, and a height of approximately 1/2 to 1/3 of the furnace side wall height. The optimum range is for the length to be in the range from 1/16 to 1/20 of the circumference and for the height to be approximately 1/3 of the side wall height, because a panel of this size can be manufactured without bending the base plate to the contour of the shell.

The thickness of the plate is principally decided by considering: (1) the weldability of the water channels thereto; (2) the rigidity and strength for holding the original shape; and (3) obtaining the largest possible heat conductivity. The former two conditions can be satisfied by a relatively thick plate, while the latter requires a light plate. An elastic structure is preferred to minimise heat distortion, and therefore too thick plates should be avoided. With these conditions taken into account, plates from 6 to 30 mm thick are used.

The configuration of the base plate can arbitrarily be determined for use in making a panel of the present invention, but the most preferable shape is rectangular although any configuration could be manufactured to meet special requirements.

If the length of the plate is not less than approximately 1/12 of the shell circumference, it should be bent or curved to conform to the furnace shell contour. However, a plate which typically is less than 1/16 of the shell circumference need not be bent.

A suitable thickness for the fins is from 1/3 to 4/3

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of that of the base plate. The distance by which each fin protrudes from the base plate should be at least 30 mm to support slag, and although the maximum practical amount of protrusion is considered to be 150 mm, no upper limitation is imposed.

A spacing of the fins is from 40 to 100 mm, depending on the installation location of the panel or on the variation in the heat load in the electric furnace. A smaller spacing is preferred if the panel is to withstand a large heat load. In this connection, care should be taken during fabrication that a fin is not affixed (for instance by welding) immediately opposite the weldment of the water channel on the other side of the base plate.

The provision of water channels, which are an important feature of this invention, will be described below. Subject to the limitations discussed below, almost any configuration for the channels can, in principle, be selected, so long as water can flow therethrough.

It is necessary for the space between adjacent channels on the base plate to be open outward away from the base plate, as shown in the specific embodiments described below, in order that welding of the channels as close together as possible may take place on the base plate. The thickness of the material from which the channels are made must be heavy enough to allow proper welding to the base plate, and specifically the material should be from  $1/3$  to  $4/3$  of the thickness of the base plate. However, it is preferred for the thickness to be not less than 3 mm.

The water-flow area defined by the channel and the base plate should be designed so as to permit a water velocity of from 1 to 5 m/sec, so that a water flow rate of from 7 to 20 tons/hr/m<sup>2</sup> of water, which has empirically been found appropriate, can be accommodated. The required area for the water flow is for example, approximately 4 cm<sup>2</sup> to obtain a flow of 7 tons/hr/m<sup>2</sup> at a velocity of 5 m/sec and approximately 56 cm<sup>2</sup> to obtain a flow of 20 tons/hr/m<sup>2</sup> at a velocity of 1 m/sec.

Each channel defining the cooling water path is preferably of arcuate cross-section, in the form of a section of a tube welded to the base plate. In such a case, the distance from the face to the base plate to the top of the channel should correspond to  $1/3$  to  $2/3$  of the diameter of a tube from which the channel is formed (i.e.  $1/6$  to  $1/3$  of the radius of curvature of the channel) and the spacing of the points of contact between the legs of the channel and the base plate should be from 30 to 150 mm.

The channels described above are affixed by welding to the entire surface of the base plate and an appropriate element is also welded to connect adjacent open ends of the channels to define the required cooling water path. The water inlet and outlet are also appropriately welded to the channels at the ends of the required cooling path.

This invention extends to an electric arc furnace having a furnace shell including side walls, there being at least one water-cooled panel fitted into the side walls which panel comprises a metal base plate of 6 to 30 mm thick, a length of not more than  $1/8$  of the furnace shell circumference and a height of not more than  $2/3$  of the height of the furnace side walls,

a plurality of fins projecting from the face of the base plate confronting the furnace interior, each fin having a thickness of  $1/3$  to  $4/3$  that of the base plate and spaced from the adjacent fin by from 40 to 100 mm, each fin projecting by at least 30 mm from the base plate, a cooling water path defined by a plurality of metal channels each defining a water flow area of from 4 to 56 cm<sup>2</sup> and having a thickness of from  $1/3$  to  $4/3$  that of the base plate, each channel being welded to the base plate on the face thereof opposed to that carrying the fins, a connecting element being welded to the base plate and to adjacent channel ends to complete a continuous water flow path from one channel to the adjacent channel, the channels at the ends of the flow path being provided with a water inlet and a water outlet, and at least one fixture mounted on the face of the panel opposed to the fins fastening the panel to the shell of the furnace, the points of attachment of the fins to one face of the base plate being non-aligned with the points of attachment of the channels to the other face of the base plate.

By way of example only, certain specific embodiments of this invention will now be described, reference being made to the accompanying drawings, in which:-

Figures 1 (a), (b), (c) and (d) respectively show a cross-sectional view of alternative forms of member forming water channels in a water-cooled panel according to the present invention;

Figure 2 is a sketch of an example of a complete water-cooled panel according to this invention;

Figure 3 is a front view of the panel of Figure 2;

Figure 4 is a front view of another type of water-cooled panel of this invention;

Figures 5 (a), (b), (c) and (d) respectively show various arrangements of the water channels in a panel according to the present invention;

Figures 6 and 7 are fragmentary cross-sectional views through two embodiments of panel of this invention;

Figure 8 is a front view of a water channel connecting tube used in various embodiments of this invention;

Figure 9 shows an example of the arrangement of the water channels on the base plate in the region to be connected;

Figure 10 is a detailed side view of part of the arrangement of Figure 9;

Figure 11 is a developed drawing of the side walls of an electric furnace in which are embedded panels of this invention;

Figure 12 illustrates the cooling effects of a panel of this invention; and

Figures 13 and 14 are sketches showing modifications of the water-cooled panels according to the present invention.

Referring to Figures 2 and 3, there is shown an embodiment of a water-cooled panel for use in an UHP electric arc furnace, arranged in accordance with this invention. Various required fixtures are normally provided for mounting the panel in the shell of an electric arc furnace, but these are not shown in Figure 2. The panel of Figures 2 and 3 comprises a base plate 1 having welded to one side



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thereof a plurality of fins 2 and to the other side thereof water channels 3. Elements 4 are provided at the ends of the channels to interconnect the same so as to define a continuous channel from a water inlet 5 to a water outlet 6. In Figure 3, two fixtures 7 are shown, which fixtures are adapted for mounting the panel in an electric furnace.

Figure 4 shows an alternative shape of panel of this invention, having a different configuration of interconnected water channels. Figures 5(a) to 5(d) show four alternative configurations of interconnected water channels for a panel the shape shown in Figure 4, the configurations of Figures 5(b) to 5(d) having two distinct water paths each having a water inlet 5 and a water outlet 6.

Figures 6 and 7 show two possible cross-sections for the panels of Figures 2 to 5(d), Figure 6 showing rounded channels 3 welded to the base plate 1 on the side thereof opposed to fins 2, and Figure 7 showing channels 3 of triangular shape. Figures 1(a) to 1(d) show four possible forms for the channels, including those of Figures 6 and 7.

Figure 8 shows a possible form of connecting element for disposition at the ends of parallel channels 3 to interconnect the same. The element is formed from the same material as the channels 3, and solid lines 8 show where the element (originally also of channel-like form) is cut. Before the channels 3 are welded to the base plate 1, they are cut at 45° as shown in Figure 9, and then the element 4 can be welded both to the channels 3 and the base plate 1 to complete the water flow circuit. This is the simplest way of providing a continuous water path through the channels 3 of the panel.

It is important for a channel 3 and a connecting element 4 to be chamfered internally where the channel or element is to be welded to the base plate. In Figure 10, the hatched area 10 shows the deposited weld metal when two channels 3 are welded to the base plate 1, the penetration in the latter being shown at 9. Advantages of chamfering in the manner shown in Figure 10 are that there is a better cooling effect by the water at this location and that it is easier to weld the channels closely adjacent one another.

The spacing between the channels should be larger if they are chamfered externally. Any generally practised welding method, such as arc welding or gas welding, can be adopted.

The panels according to this invention and described above can be modified by welding along one or more side edges of the base plate water-cooling tubes. The panels described above are capable of performing well in a furnace, but there is no denying that the cooling effect is not so good at the side edges as it is in the central region. Figure 12 shows an edge portion of a panel subjected to heat, and it can be seen that the edge itself is at a relatively high temperature. A similar effect can be detected along an edge perpendicular to the channels 3.

These effects become significant in determining the life of a panel, especially if the panel is subjected to high heat loadings. This problem has been solved by welding tubes to the adversely affected edge or edges of the panel, and circulating the cooling water through the tubes. The tubes should have a cross-

sectional water-carrying area similar to that of the channels to which the tubes are connected, unless the tubes are provided with independent water supply and exhaust ducts. Figure 13 shows an example where three edges are protected by tubes 12 welded to the base plate and forming a part of the water circulation flow path by being connected to the channels 3. Figure 14 shows another example where the tube 12 is welded along the entire bottom edge of the panel.

A panel constructed as described above is installed at a hot spot or other location in the shell of the electric furnace, and when the furnace is operated water is circulated through the channels of the panel. Slag splashing on to the front surface of the panel is supported by the fins 2 to form considerably thick layers serving as thermal and electrical insulators and also as a mechanical protective layer. The quantity of the cooling water used typically is from 7 to 20 tons/hr/m<sup>2</sup>, depending on the thermal loading at the installation location in the furnace.

The specific construction of various panels as described above will now be discussed in detail. These panels were designed and manufactured according to Figures 2 and 3, for use in a UHP furnace with an inside shell diameter of 5.8 m.

A commercially-available rolled steel plate (SM 50) of 16 mm thickness was cut to form a base plate 1,710 mm wide x 610 mm high, which base plate was bent to the shell contour. Fins 1,710 mm wide and 60 mm long, to fit to the shell contour, were cut out of a rolled steel plate (SS 41) 12 mm thick. Six fins were welded to the front face (i.e. concave side) of the base plate at a spacing of 10 mm. Six tubes each of 90 mm outside diameter and 7.6 mm wall thickness were cut in half longitudinally and bent to the shell contour. The halved tubes were chamfered internally and arranged lengthwise with 8 mm spacing (as a welding allowance) on the base plate and then welded in position. The connecting elements were made out of the same tube and were prepared as shown in Figure 8. These were then welded to the ends of the water channels defined by the halved tubes welded to the base plate. Blanking plates were welded to the ends of the channels and water inlet and outlet pipes fitted.

Fixtures 7 and 7' (Figure 3) were constructed for fastening the panel to a furnace shell by welding two 110 mm-square plates to a pair of adjacent channels, and then welding nuts with an outside diameter of 85 mm and threaded holes of 36 mm to those plates. A transportation hanger 11 was attached to the panel as shown in Figure 3.

Panels of various sized were manufactured to fit within a furnace shell, and then were embedded in the shell, as shown in Figure 11. This Figure is a developed view of the furnace side wall, the upper end thereof being shown at 21, and the lower thereof at 22. An operation door 23 and a side door 24 are also shown. The cross-hatched panels embedded in the side walls are in accordance with this invention, whereas the other single-hatched panels are of a known type. The area below the panels is made of refractory materials. Panels 26, 28, 30 and 31 are constructed in accordance with basic aspects of the

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invention, panel 26 being of the type shown in Figure 3. Panels 25, 27, 29, 32 and 33 are modified panels but still in accordance with this invention, panels 25 and 32 being of the type shown in Figure 13.

- 5 When all these panels were put into practical use with water circulation, the panels of this invention became coated with slag, 70 mm thick at the thickest points, 2-3 mm thick in some points at the extremities of the fins, the average being 20-40 mm
- 10 thick. This slag coating formed a protective layer. 16 tons/hr/m<sup>2</sup> of cooling water were supplied to heavily thermally loaded locations and 12 tons/hr/m<sup>2</sup> to lightly thermally loaded areas, the average being 14 tons/hr/m<sup>2</sup>. These panels operated satisfactorily for
- 15 6 months without any trouble and for another 6 months after minor repair work.

The major features of the panels described above of this invention are:

- 1) For a given volume flow rate, the water velocity
- 20 through the relatively narrow water channels is high as compared to the velocity through a known box-type panel for a furnace, with or without water-regularion partitions. This high flow rate gives a good cooling effect not adversely affected by
- 25 sedimentation of material suspended in the cooling water.

- 2) The panel is fabricated on a single base plate and thus is elastic as a whole and immune from early cracking often found in box-type panels, caused by
- 30 heat stress concentrations at certain locations. The panel according to the present invention is free from this disadvantage and hence much safer.

- 3) The panel of this invention is much superior to a box-type panel so far as manufacturing costs are
- 35 concerned; typically these are 3/4 of those of a similar box-type panel. Also, the panel of this invention is much easier to handle, install and maintain.

- Moreover, there is another advantage in that the panel can be manufactured to almost any desired
- 40 configuration, while the known types of panels are limited in the possible configurations.

- 4) From the safety aspect, it is possible to use an extra water supply system for some period of time in an emergency if one system is out of order or is
- 45 forced to be closed, if there are duplex water supply paths defined by the channels welded to the base plate, as illustrated in the embodiments of Figures 5 (b), (c) and (d).

- 5) As compared to various known water-cooled
- 50 panels for use in the side walls of an electric furnace, including cast panels defining the water passage-ways or panels fabricated by welding bundles of pipes together, the panel of this invention displays great improvements insofar as it is relatively easy to
- 55 manufacture and handle, it is simple to inspect and maintain when in use, and furthermore it can be given almost any required configuration.

#### CLAIMS

- 60 1. A water-cooled panel adapted for use in an electric furnace, which panel comprises a metal base plate of 6 to 30 mm thick, a length of not more than 1/8 of the furnace shell circumference and a height
- 65 of not more than 2/3 of the height of the furnace side

- walls, a plurality of fins projecting from the face of the base plate adapted to confront the furnace interior, each fin having a thickness of 1/3 to 4/3 that of the base plate and spaced from the adjacent fin by
- 70 from 40 to 100 mm, each fin projecting by at least 30 mm from the base plate, a cooling water path defined by a plurality of metal channels each defining a water flow area of from 4 to 56 cm<sup>2</sup> and having a thickness of from 1/3 to 4/3 that of the base plate, each channel being welded to the base plate on the
- 75 face thereof opposed to that carrying the fins, a connecting element being welded to the base plate and to adjacent channel ends to complete a continuous water flow path from one channel to the adjacent
- 80 channel, the channels at the ends of the flow path being provided with a water inlet and water outlet, and at least one fixture mounted on the face of the panel opposed to the fins for fastening the panel to the shell of the furnace, the points of attachment of the fins to one face of the base plate being non-
- 85 aligned with the points of attachment of the channels to the other face of the base plate.

2. A water-cooled panel according to claim 1, wherein the length of the base plate is not less than
- 90 1/24 of the furnace shell circumference.

3. A water-cooled panel according to claim 2, wherein the length of the panel lies in the range of from 1/16 to 1/20 of the circumference of the furnace shell circumference.

4. A water-cooled panel according to any of claims 1 to 3, wherein the height of the base plate lies in the range of from 1/3 to 1/2 of the height of the furnace side walls.

5. A water-cooled panel according to any of the
- 100 preceding claims, wherein each fin projects from the base plate by an amount of from 30 to 150 mm from the base plate.

6. A water-cooled panel according to any of claims 1 to 5, wherein the channels defining the cooling water path each have an arcuate cross-section, the distance from the face of the base plate to the top of the channel corresponding to 1/6 to 1/3 of the radius of curvature of the arcuate channel, and the spacing of the points of contact between the legs of the channel and the base plate being from 30 to 150
- 110 mm.

7. A water-cooled panel according to any of claims 1 to 5, wherein the channels defining the cooling water path each have a polygonal cross-section.

8. A water-cooled panel according to any of the preceding claims, wherein the channels defining the cooling water path are arranged to extend parallel to the length of the base plate.

9. A water-cooled panel according to any of claims 1 to 7, wherein the channels defining the cooling water path are arranged to extend parallel to the height of the base plate.

10. A water-cooled panel according to any of the preceding claims, wherein a tube is welded to at least one of the side edges of the base plate, which tube forms a part of the cooling water path.

11. A water-cooled panel according to any of the preceding claims, wherein the base plate is curved to the contour of the shell of the furnace.

12. A water-cooled panel according to any of
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claims 1 to 10, wherein the base plate is planar.

13. A water-cooled panel according to claim 1 and substantially as hereinbefore described, with reference to and as illustrated in any of the Figures of the accompanying drawings.

14. An electric arc furnace having a furnace shell including side walls, there being at least one water-cooled panel fitted into the side walls which panel comprises a metal base plate of 6 to 30 mm thick, a length of not more than  $1/8$  of the furnace shell circumference and a height of not more than  $2/3$  of the height of the furnace side walls, a plurality of fins projecting from the face of the base plate confronting the furnace interior, each fin having a thickness of  $1/3$  to  $4/3$  that of the base plate and spaced from the adjacent fin by from 40 to 100 mm, each fin projecting by at least 30 mm from the base, a cooling water path defined by a plurality of metal channels each defining a water flow area of from 4 to 56 cm<sup>2</sup> and having a thickness of from  $1/3$  to  $4/3$  that of the base plate, each channel being welded to the base plate on the face thereof opposed to that carrying the fins, a connecting element being welded to the base plate and to adjacent channel ends to complete a continuous water flow path from one channel to the adjacent channel, the channels at the ends of the flow path being provided with a water inlet and a water outlet, and at least one fixture mounted on the face of the panel opposed to the fins fastening the panel to the shell of the furnace, the points of attachment of the fins to one face of the base plate being non-aligned with the points of attachment of the channels to the other face of the base plate.

15. An electric furnace as claimed in claim 14, wherein the water-cooled panel fitted in the furnace side walls is configured as claimed in any of claims 2 to 13.

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- ☐ **SKEWED/SLANTED IMAGES**
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